Contract No. TBD

Exhibit I

Mars Landing Radar Antenna Array Functional Requirements Document

Version 1.1

August 21, 2003

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REVISION SHEET

VERSION	***DATE***	***AFFECTED PAGES***	***NOTES***
1.1	8/21/03	Multiple	Added page 2, Revision Sheet. Added page 3, Document Scope. Added Figure 1, Conceptual layout of the PATR sandwich. Added Figure 2, MSL PATR Profile. Paragraph 1: Added reference to Figure 2. Table 1: Added comments for Radiation Efficiency parameter. Revised Sidelobe Performance specification to PSLR <-13dB and deleted ISLR requirement. Added Single, non-switchable polarization to Polarization specification. Revised Bandwith specification to 30 – 34 GHz required and 30 – 35 GHz goal. Revised Return Loss specification to >20 dB goal. Paragraph 2.2: Revised positional accuracy requirement to 0.4 mm. Table 2: Revised Positional Accuracy specification to 0.4 mm. Added comments and additional note for Minimum isolation between any two elements parameter. Paragraph 3.2: Revised reference to Figure 1 to Figure 3. Previous Figure 1, Mass Acceleration Curve: Redesignated as Figure 3.

Document Scope

This document establishes the functional requirements for the Mars Landing Radar Antenna Array. This antenna array shall be one of the three subsystems of a Ka-band Phased Array Terrain Radar (PATR), which will map the local topography of the Martian surface during the final stages of the landing operations for the 2009 Mars Science Laboratory (MSL).

The half-meter (nominal; dimension may be as large as 0.65 meters) diameter, ten centimeter thick radar will consist of three subsystems: a 128 element antenna array, 16 sets of 8 element T/R modules with feed networks which make up a signal generating/receiving subsystem, and a data processing, timing and command subsystem. In addition to the operational components of the landing radar, the associated fixture and mounting hardware to make the system compact and durable enough so as to qualify for space flight will be an integral part of the completed system. Requirements contained in this document are applicable to the graduated development and fabrication of the 128 element array subsystem, which will constitute the front portion of the terrain radar.

Physically, PATR will be constructed like a sandwich (Figure 1), with the array being the front portion, the feed network the middle, and the T/R modules and digital logic forming the back portion. The mechanical interface between the portions of the sandwich will be determined in part by the Contractor's mechanical design for the antenna array.

Figure 2 shows a conceptual profile of the MSL PATR system. Note that parts (A) and (B) are drawn to different scales. Part (A) is the antenna array elements and structure. Part (B) is a multi-layer circuit board whose exact design is TBD. Part (A) shall be designed to mate with a microstrip or stripline feed system that will be included in Part (B). The exact interface is TBD and the Contractor may suggest configurations that are compatible with their antenna design concept.

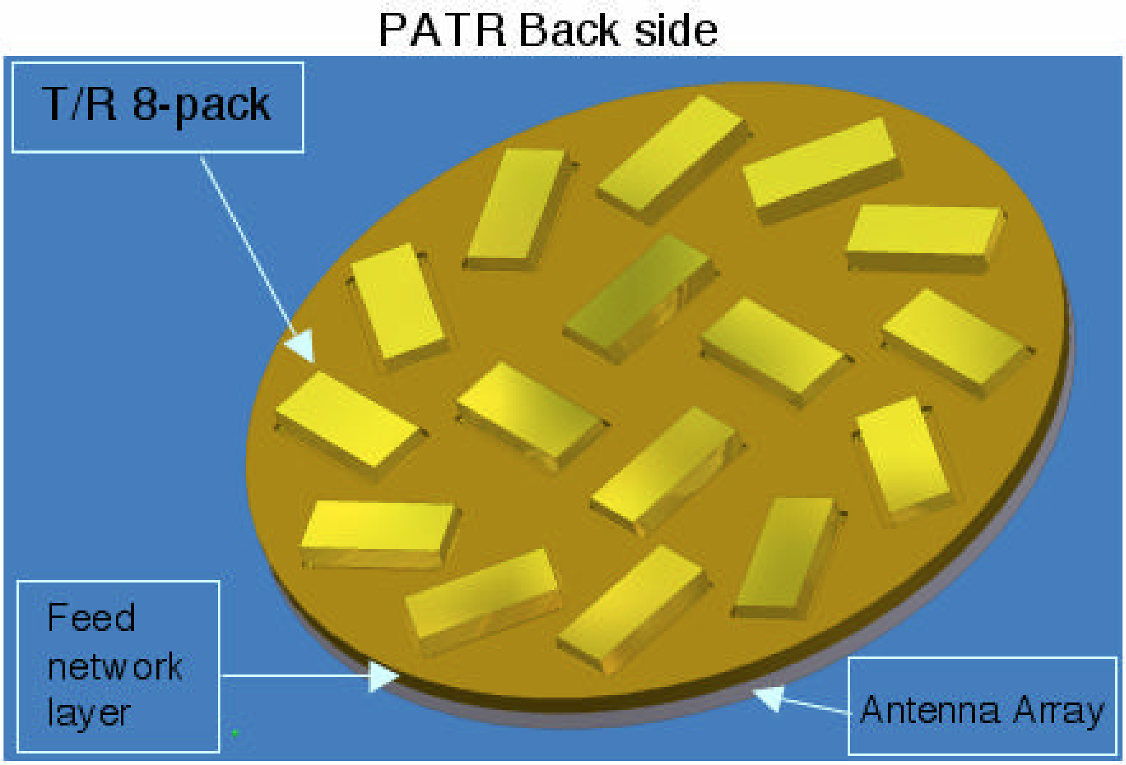

Figure 1. Conceptual layout of the PATR sandwich

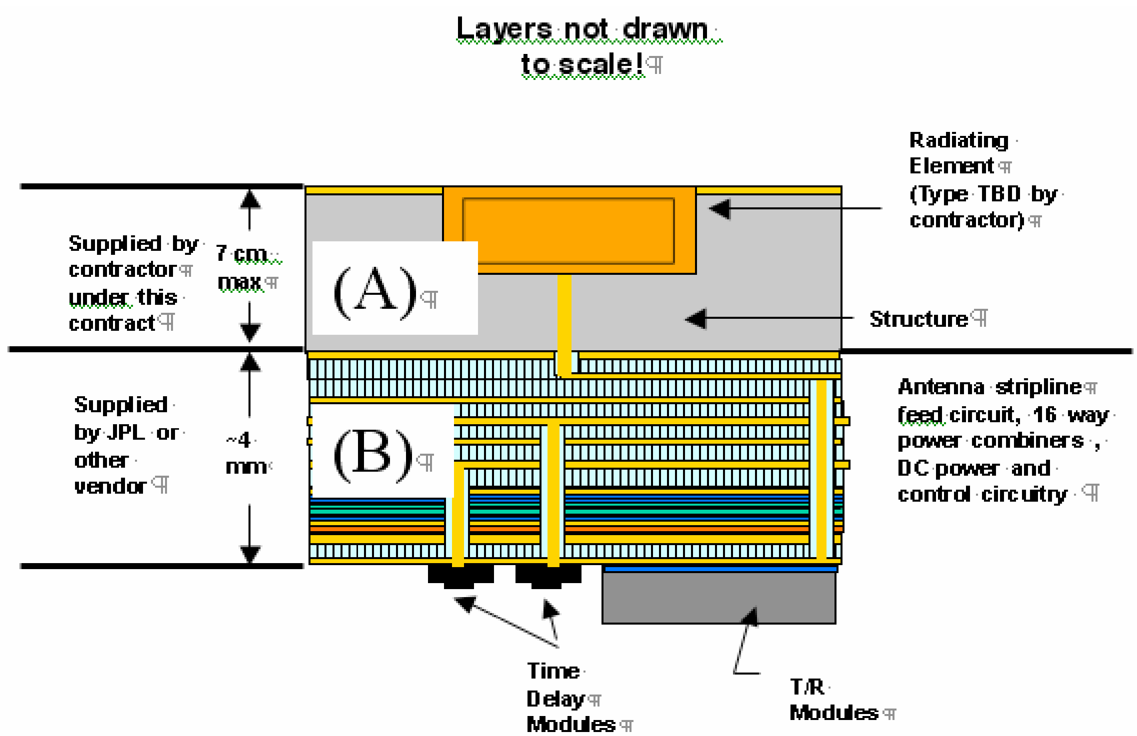

Figure 2. MSL PATR Profile

Technical Specifications

1. Functional Requirements for the Array Elements

The final antenna array shall consist of some 128 individual passive elements which will be driven through the array backside via stripline or microstrip feed by a set of 16 eight-element T/R modules (Figure 2). While the goal for this Contract is for an array of elements, the array performance will be strongly influenced by individual element characteristics. The electrical and physical characteristics of the array elements are described in Table 1.

Table 1. Technical specifications for a single element design of antennas making up the Phased Array Terrain Radar (PATR) array. Requirement and goal specifications apply to both prototype and flight-qualified components.

Parameter	Specification	Comments
Beamwidth	30 degrees HPBW required	Symmetric in azimuth and elevation
Vertical Dimension	< 7 cm required, < 4 cm goal	
Radiation Efficiency	> 30 % required > 60 % goal	Efficiency = (Power radiated in main beam / Power on microstrip or stripline immediately before feed interface to element)
Sidelobe performance	PSLR < -13 dB required	
Feed	Microstrip or stripline (50 ohm nominal)	
Polarization	Circular or linear. Single, non-switchable polarization.	Polarization may be chosen to minimize depth of antenna element
Bandwidth	30-34GHz required, 30-35 GHz goal	
Peak power handling	50 mW required	
Weight	< 23 grams required < 8 grams goal	
Return Loss	> 20 dB goal	

1.1 Electrical Interfaces

Individual elements of the array shall be fed through the backplane of the array, either through stripline or microstrip. The exact choice of feed is left up to the Contractor so as to increase flexibility in the design. In general, the feed should be chosen to minimize the array depth and overall weight without violating the efficiency requirements for the element interface.

2. Functional Requirements for the Antenna Array

The overall 128 element array shall be contained within a 0.5 m (nominal; see table for details) diameter fixture. The array itself shall be the principal mechanical structure for the space that it occupies. Hence, in addition to the weight and electrical characteristics, the array must be shown to be mechanically rigid while occupying a minimum of vertical space. As discussed in the statement of work the array development shall take place in three stages. The first stage consisting of a 16 element subset of the larger 128 element array.

2.1 Mechanical Envelope

Dimensions of the 16 element subarray shall be 15 cm in diameter and less than 7 cm in depth. Dimension of the 128 element full array, as mentioned above, shall be 0.5 to 0.65 m in diameter and less than 7 cm in depth.

2.2 Element Positions

Position of elements within the array will be selected by JPL, with a positional accuracy requirement of better than 0.4mm. In general, element placement will be random, decreasing in radial density as a function of the radial distance from the array center (in order to reduce grating lobes and sidelobes).

A summary of the electrical and physical characteristics of the full array is described in Table 2.

Table 2. Technical specifications for the antenna array design (applies to both flight-qualified and prototype arrays).

Parameter	Specification	Comments
Number of Elements	128 required	16 elements for the first phase of array development
Positional Accuracy	< 0.4 mm in all dimensions required	
Net weight (including elements)	< 3 kg required, < 1 kg goal	
Diameter	0.5 m nominal	Diameter may increase to 0.65 meters; the number of elements will stay the same however
Minimum isolation between any two elements	< -20 dB required < -30 dB goal	Measured at minimum 3 cm center to center element spacing.* See Note below

*Note: Assumes that the coupling monotonically decreases for larger separations. If the coupling is larger than the requirement at a 3.0 cm spacing, then the Contractor shall specify a planar dimension for the element which is larger than the actual element size, yet meets the isolation requirement specified in Table 2. Similarly, if the element size is larger than 3.0 cm, then the Contractor shall measure the coupling at their minimum element spacing, but shall also report the spacing at which the coupling was measured.

In addition to the above requirements and goals, some interaction with the JPL RF team will be required to mechanically and electrically interface the array to the remainder of the PATR subsystems.

3. Mechanical Characteristics

The combination of the antenna elements and antenna array (with fixture) shall be of solid construction and withstand vibrational and temperature stresses commensurate to those encountered with during launch, transit and entry into the Martian atmosphere. The following details a list of mechanical and thermal constraints, which have been tailored for the PATR system from a "baseplate" typically used for providing a first estimate for these requirements. Gross differences between what is possible and what is required should be referred back to the JPL Contract Technical Manager and Contract Negotiator.

3.1 Flight-Qualified Versus Prototype Array Requirements.

While the following technical specifications relating to the mechanical characteristics are for the flight-qualified units, it is expected that the prototype array shall achieve similar mechanical performance in anticipation of the construction of the flight-qualified units.

3.2 Load Limits

The PATR structures and their mounting interfaces shall be designed to the limit loads defined in Figure 3, Mass Acceleration Curve (MAC).

The MAC limit load factors, which are based on the total mass of each subsystem, shall be applied at the center of gravity of each subsystem in their launch configuration, and in the direction yielding the most critical loads. The direction of the most critical load being in the vertical direction (10 cm overall thickness) of the array and RF components. In the instance of the array design only (i.e. requirements set by this Contract), critical loading shall be determined over the vertical extent of the submitted design.

3.3 Strength

Materials: The PATR shall use property data, for all allowable materials, obtained from the most recent revision of MIL-HDBK-5F, "Metallic Materials and Elements for Aerospace Vehicle Structures," or from other sources approved by the JPL Contract Technical Manager. Type "A" basis material properties (99% probability and 95% confidence) or equivalent shall be used for all primary support structures.
Factor of Safety: The passive array supplied to the terrain radar shall be designed with a yield factor of safety (FS) of 1.25 and an ultimate FS of 1.5 for primary and secondary

structures which shall be qualified by static (or equivalent) testing, or with a yield FS of 2.0 and an ultimate of 2.6 for primary and secondary structures which shall not be qualified by static (or equivalent) testing.

Margins of Safety: The margins of safety of all structural elements shall be positive (greater than or equal to zero) and shall be calculated as:

$$\text{Margin of Safety} = \frac{\text{Allowable Load/Stress (yield or ultimate)}}{\text{Applied Load/Stress X FS (yield or ultimate)}} - 1 \geq 0$$

3.4 Stiffness

The PATR shall have sufficient rigidity to withstand its design loads without excessive deformation and/or deflections. Special considerations for rigidity shall be given to areas such as surfaces used as references for instrument pointing. Deformation and/or deflections shall be considered excessive if they are greater than the requirements placed on the structure or can cause unintentional deleterious contact between adjacent assemblies within the array, physical separation of any preloaded joint at limit load times the appropriate yield factor of safety, or violation of the launch vehicle dynamic envelope. The PATR and other electronics boxes, when rigidly mounted at their mounting interface, shall have a minimum resonant frequency greater than 20 Hz in any direction.

3.5 Fatigue

Fatigue shall be considered in the design of the array structural elements Material selection shall consider fatigue characteristics in relation to the design requirements of the structural elements. A safety factor of 4.0 in life is required.

3.6 Thermal Effects

Thermal stresses and thermal distortions shall be considered in the analysis of structures supporting the array. Thermal conditions, such as temperature and thermal gradient extremes, which could affect latch loads and/or structural alignments shall be analyzed or tested. Consideration shall also be given to deterioration of material properties caused by temperature changes encountered in the launch, transit and landing of the terrain radar (±40 deg. C). Previously stated yield and ultimate margins of safety shall be positive with thermal effects included.

The array shall be able to maintain its structural integrity throughout the life of the instrument. As such, materials used should be able to withstand temperatures between –65 and 75 degrees C for the six month transit time period between Earth and Mars. Additionally, the operating range of the instrument is currently stated to be between –40 and 50 degrees C. Use materials that will have a low thermal inertia (to avoid uneven thermal gradients) while maintaining overall physical shape.
The PATR shall be capable of meeting the thermal requirements specified in Table 3.

Table 3. Thermal exposure of the PATR during launch, transit and reentry to the Martian atmosphere. (applies to flight-qualified units only)

Req #	Category	Temperature Range or Rate	
		Cold	**Hot**
7.2.1	Flight Acceptance Range (functional & performance range)	-40°C	50°C
7.2.2	Qualification Range	-55°C	75°C
7.2.3	Non-operating Range (survival range)	-65°C	75°C
7.2.4	Performance Rate	1°C / minute over the FA range	
7.2.5	Qualification Rate	5°C per minute over the qualification range	

3.7 Structural Nonlinearity

Any significant structural/mechanical nonlinear characteristics shall be thoroughly investigated by analysis and/or test.

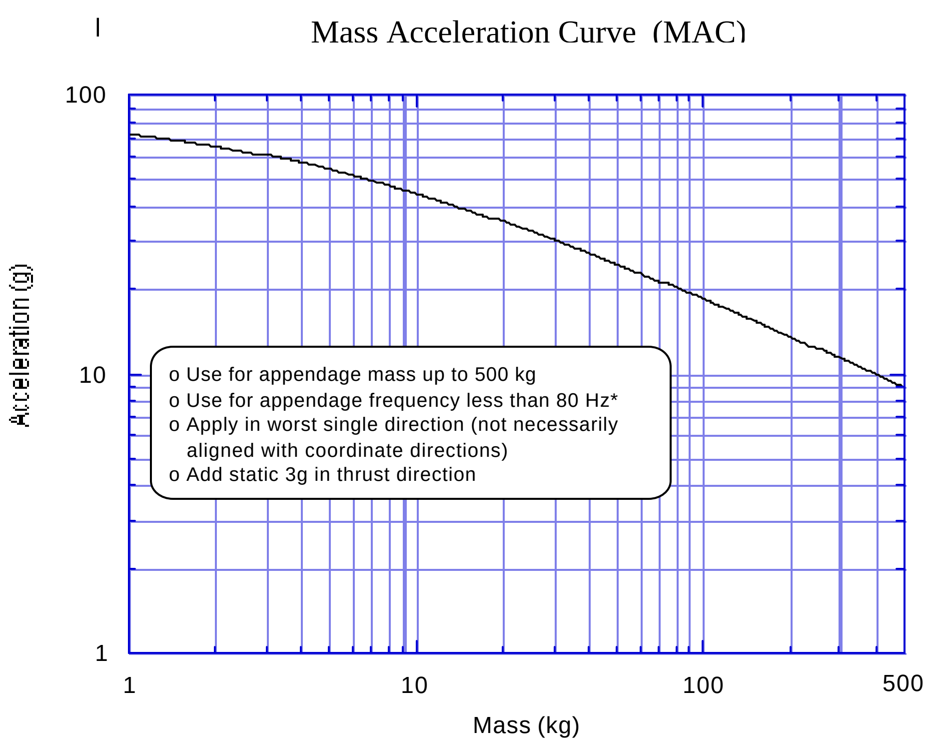

Figure 3. Mass Acceleration Curve